Binary black hole systems in nuclei of extragalactic radio sources

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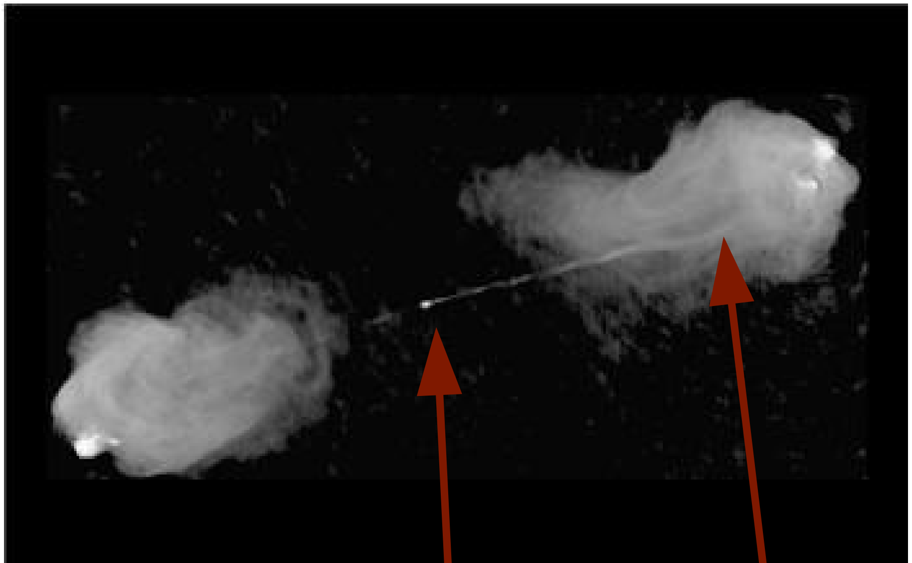
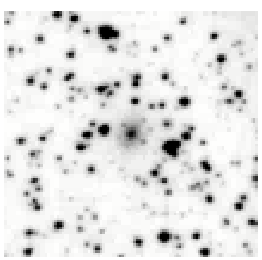
IAP

Radio galaxy Cygnus A



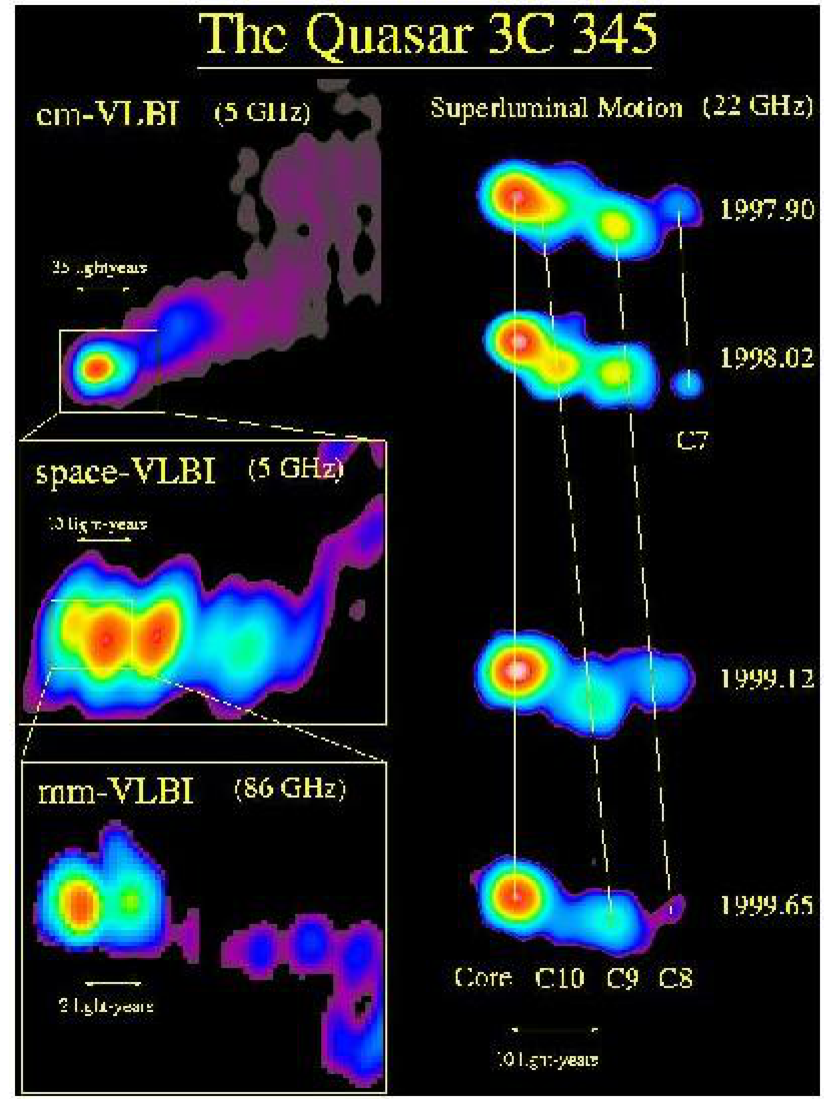
Nucleus

Extended lobe



Galaxy associated with Cygnus A : elliptical galaxy

Nucleus of 3C 345

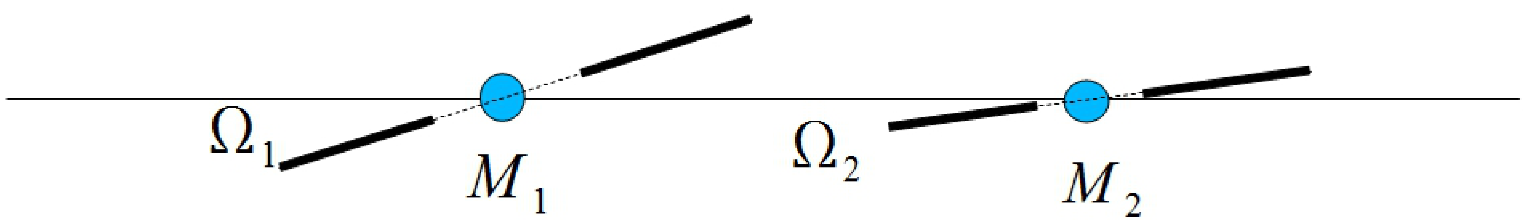


On the milli arc sec scale one observes a quasi continuous flow. It is the synchrotron emission of blobs of plasma (VLBI components) showing superluminal motion (apparent motion).

I - Modelisation of VLBI component ejections

Collaboration with the MPIfR

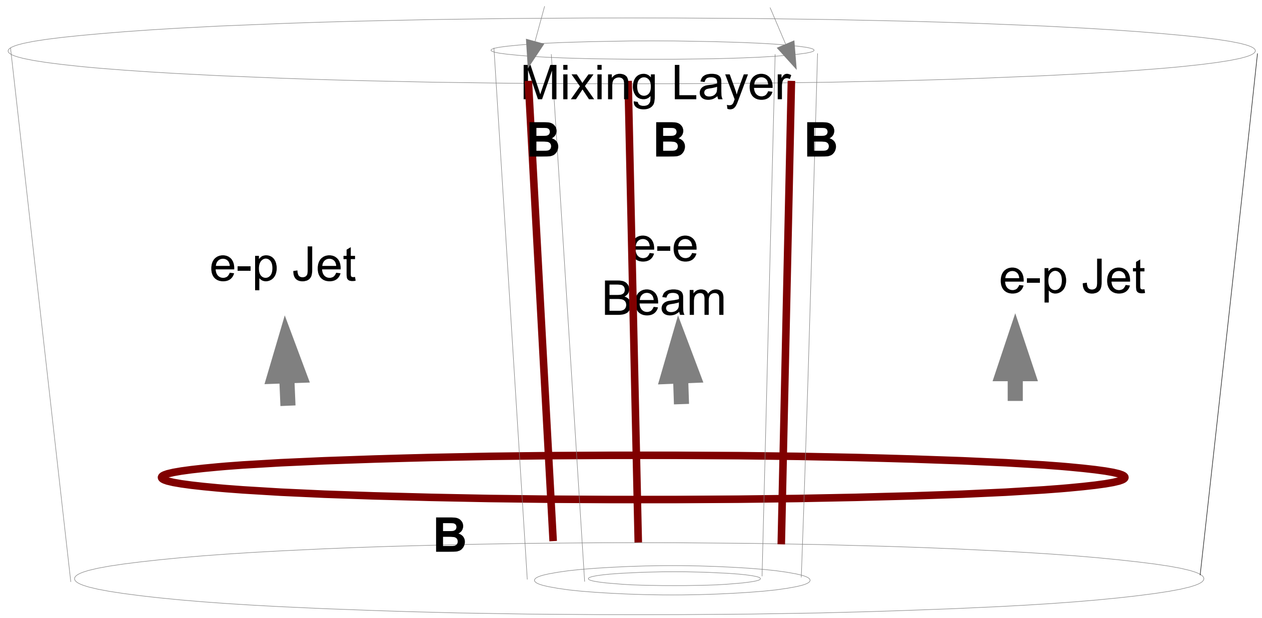
The ejection of VLBI components does not follow a straight line, but wiggles. This suggests a precession of the accretion disk. To explain the precession of the accretion disk, we will assume that the nuclei of radio sources contain BBH systems (binary black hole).



A BBH system produces three perturbations of the VLBI ejection due to

- the precession of the accretion disk,
- the motion of the two black holes around the gravity center of the BBH system
- the motion of the BBH system around something.

The two-fluid model



We will assume that nuclei of radio sources eject two fluids:

- an e^{-} - p plasma (*jet*), which speed is : $v_j \leqslant 0.4\,c$

- an e^{-} - $e+$ plasma (*beam*), which speed is : $v_b \approx c$

The beam can propagate inside the jet if : $\gamma_b \leqslant 30$

- The jet and the beam are confined by the magnetic field (non balistic ejection).

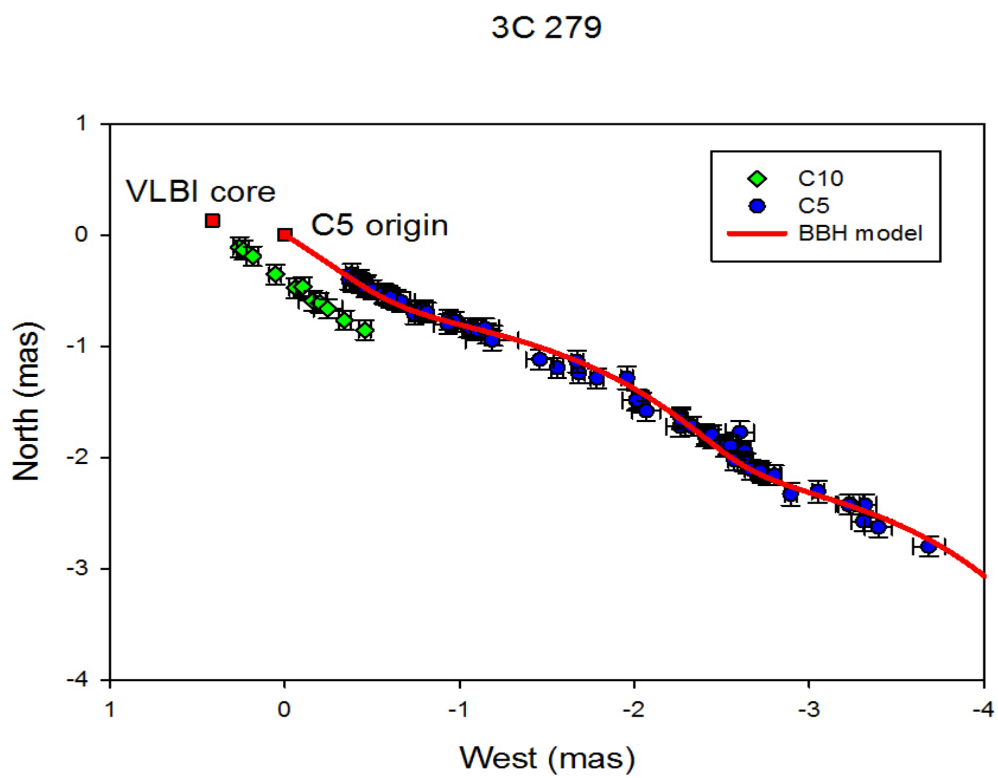
- The jet carries most of the mass and the kinetic power ejected by the nucleus, it is responsible for the formation of kpc jets, hot spots and extended lobes.

- The beam is responsible for the formation of superluminal sources and their emission from radio to γ-ray.

Consequences of the BBH model

– If the two BH eject VLBI components, we can observe

- a possible offset of the origin of the VLBI ejection, (the origin of the VLBI ejection is different from the VLBI core), → detection of the radius of the BBH system and the positions of the 2 BH, 3C 279 …
- 2 families of trajectories (different Omega, …), 3C 273, 3C 279 … if a family has is characterized by a mass ratio « a », the other family is characterized by the mass ratio « 1/a »



- All VLBI jets show wiggles indicating at least a precession of the accretion disk,

→ this may indicate that all radio sources contain BBH systems,

- Every time that we had enough data to model VLBI ejections, we found that nuclei of extragalactic sources contain a BBH system

- If nuclei of extragalactic radio sources contain BBH systems, one can understand
  - why extragalactic radio sources are associated with elliptical galaxies,
  - why more than 90% of QSO are not radio sources.

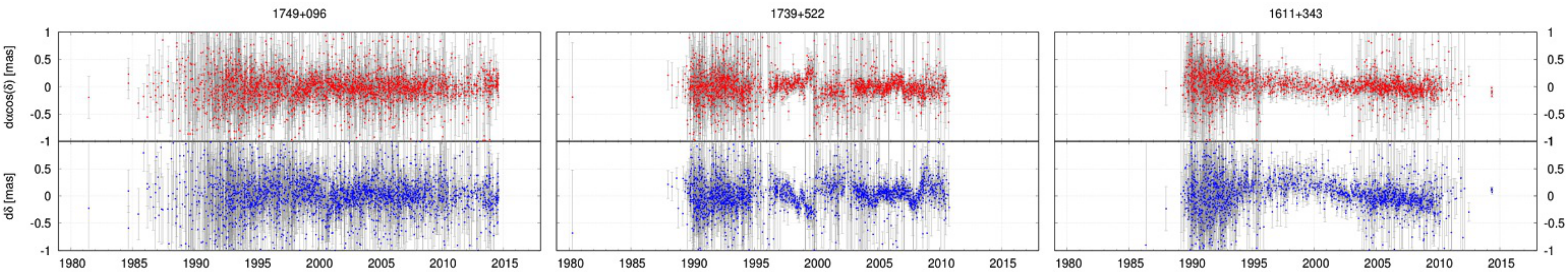
We found that the size of the BBH systems of young radio sources (GHz sources, i.e. sources without extended radio lobes) is :

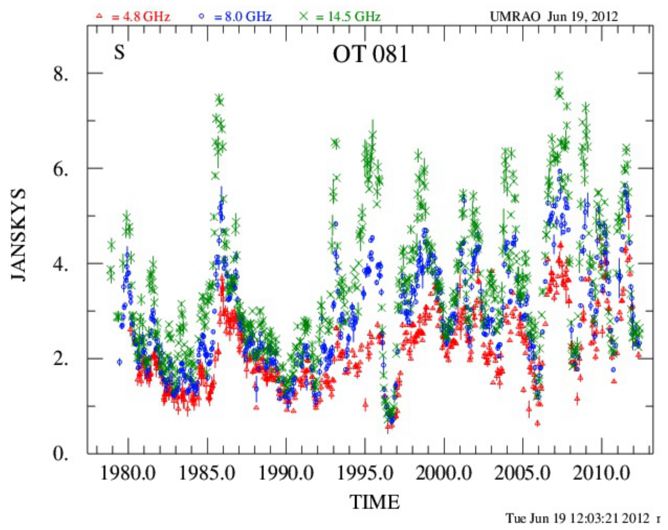
$R_{bin} \approx 1$ pc → 0.12 mas < R_{bin} < 1 mas

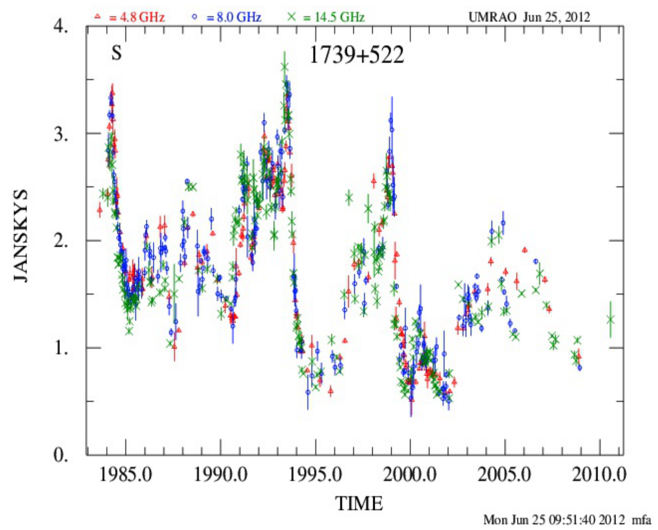
II - Geodetic surveys

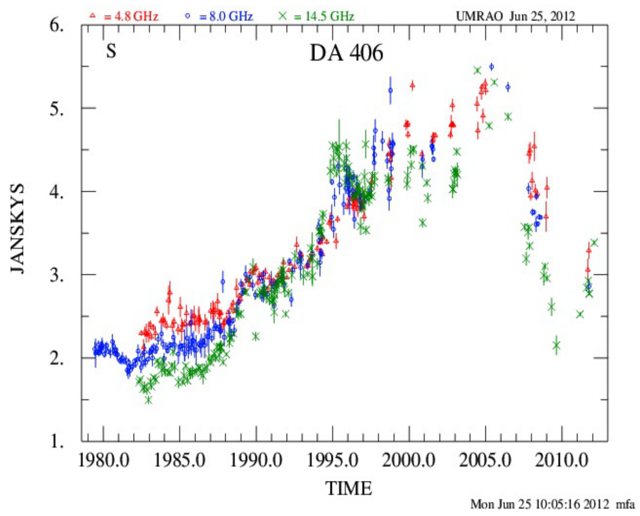
Collaboration with S Lambert (SYRTE)

Correlation between the flux variations and the time series RMS







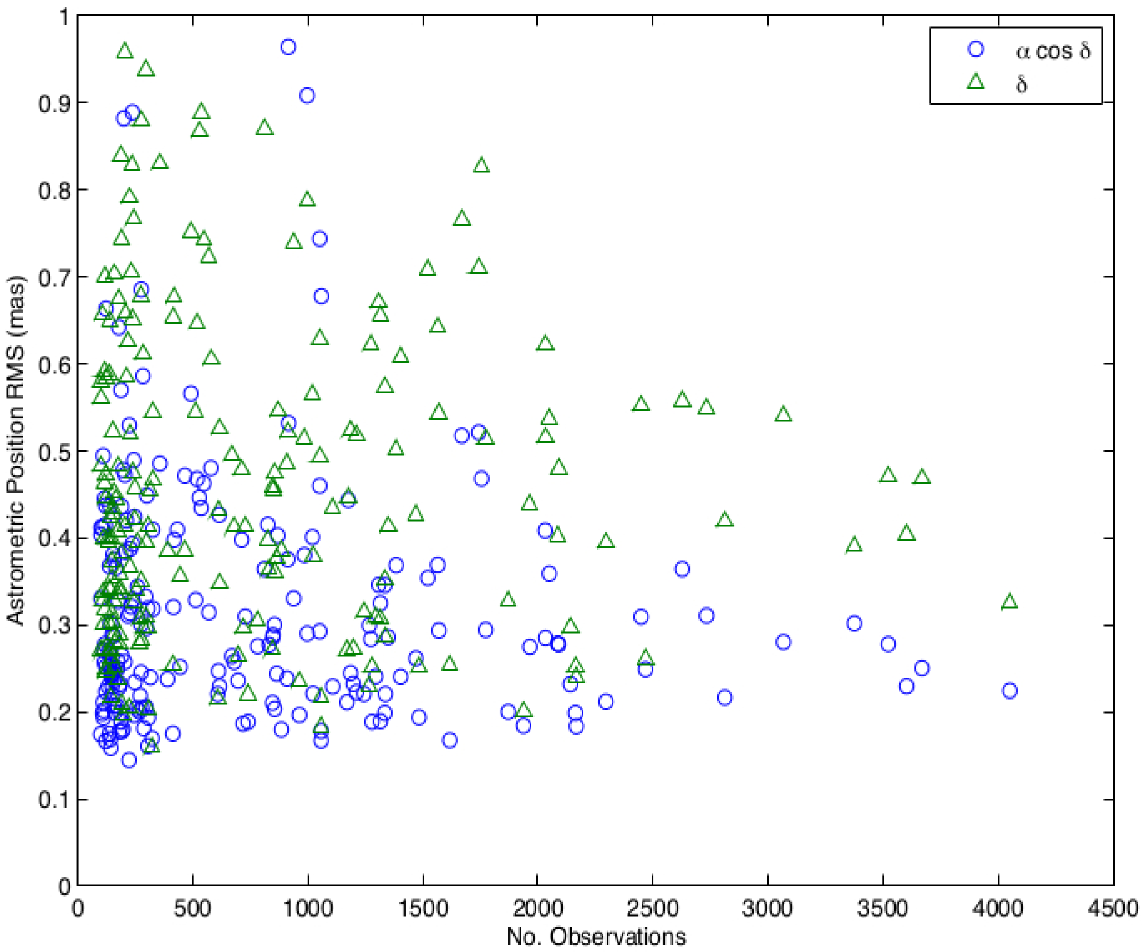


Correlation between the size of the BBH system and the RMS time series of the ICRF2 survey

	Results	Time series RMS
PKS 0420-014	contains a BBH system : Rbin ≈ 0.12 mas (Britzen et al 2001)	0.33 * 0.66
3C 345	contains a BBH systen (Lobanov & Roland 2005)	0.71 * 0.69
S5 1803+784	contains a BBH system : Rbin ≈ 0.1 mas (Roland et al 2008)	0.24 * 0.25
1823+568	contains a BBH system : Rbin ≈ 0.06 mas (Roland et al 2013)	0.23 * 0.28
3C 279	contains a BBH system : Rbin ≈ 0.42 mas (Roland et al 2013)	0.90 * 1.11
PKS 1741-03	contains a BBH system : Rbin ≈ 0.18 mas (unpublished)	0.20 * 0.23
1928+738	contains 2 BBH system : Rbin ≈ 0.22 mas (Roland et al 2015)	0.22 * 0.35
3C 345	contains 3 BH or 2 BBH systems (unpublished)	0.71 * 0.69
3C 273	contains a BBH system (unpublished)	1.08 * 1.44

We found that the time series RMS is larger than the size of the BBH system

Time series RMS



From geodetic observations, nuclei of extragalactic radio sources are not point sources (link with GAIA).

III - High frequency VLBI observations

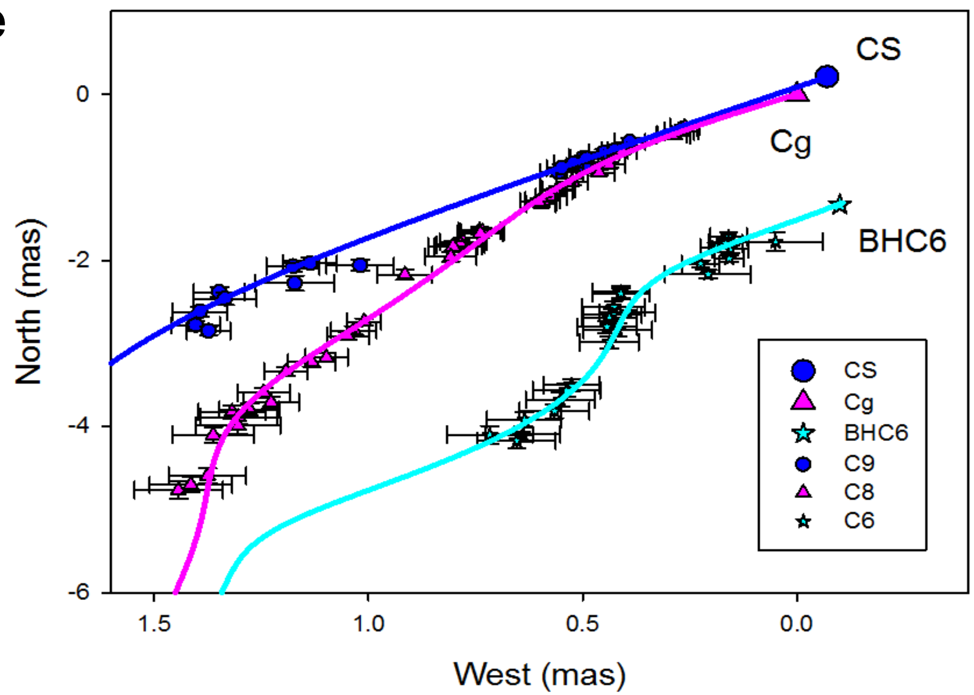
If the nucleus contains a BBH system and if the 2 BH are emitting in radio, observations at frequencies ≥ 43 GHz will allow to detect the BBH system.

In the case of 1928+738, the 2 BH are detected, components CS and Cg.

- The fit of component ejected by Cg indicates : Mcg/Mcs = 3,

- the fit of component ejected by CS indicates : Mcs/Mcg = 1/3

The case of OJ 287 : 2 stationnary components separated by 0.2 mas



IV – Evolution of the size of the BBH system

Collaboration with G Boué (IMCCE)

- « young radio sources » contain BBH systems with a typical size of 1 pc.

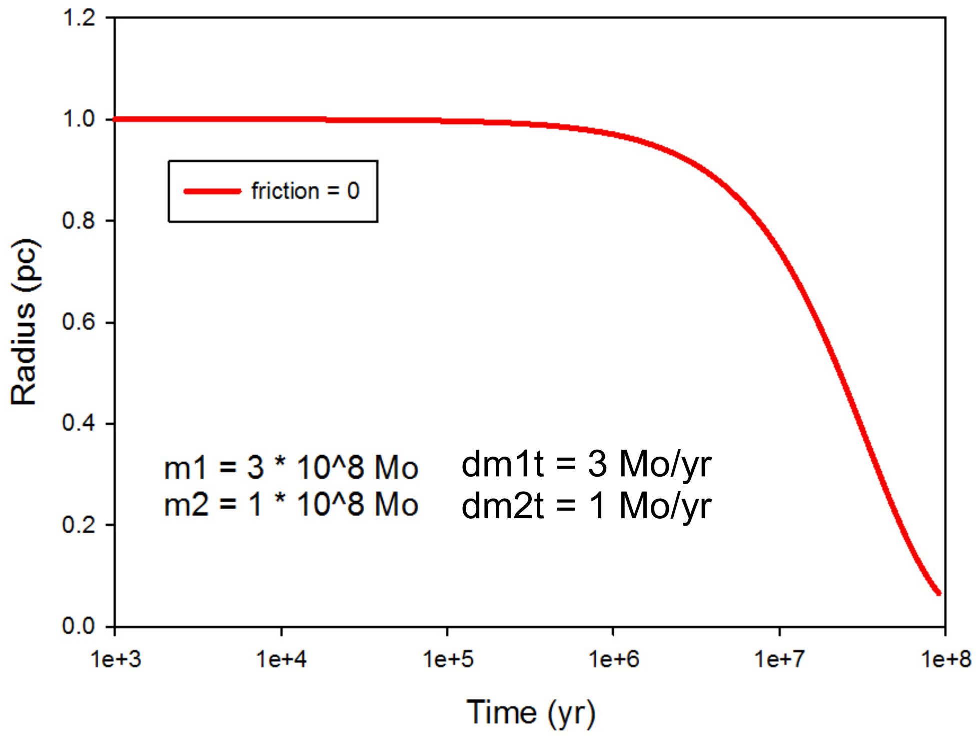
- During the life time of the radio source (≤ 10^8 yrs) the masses of the BH increase

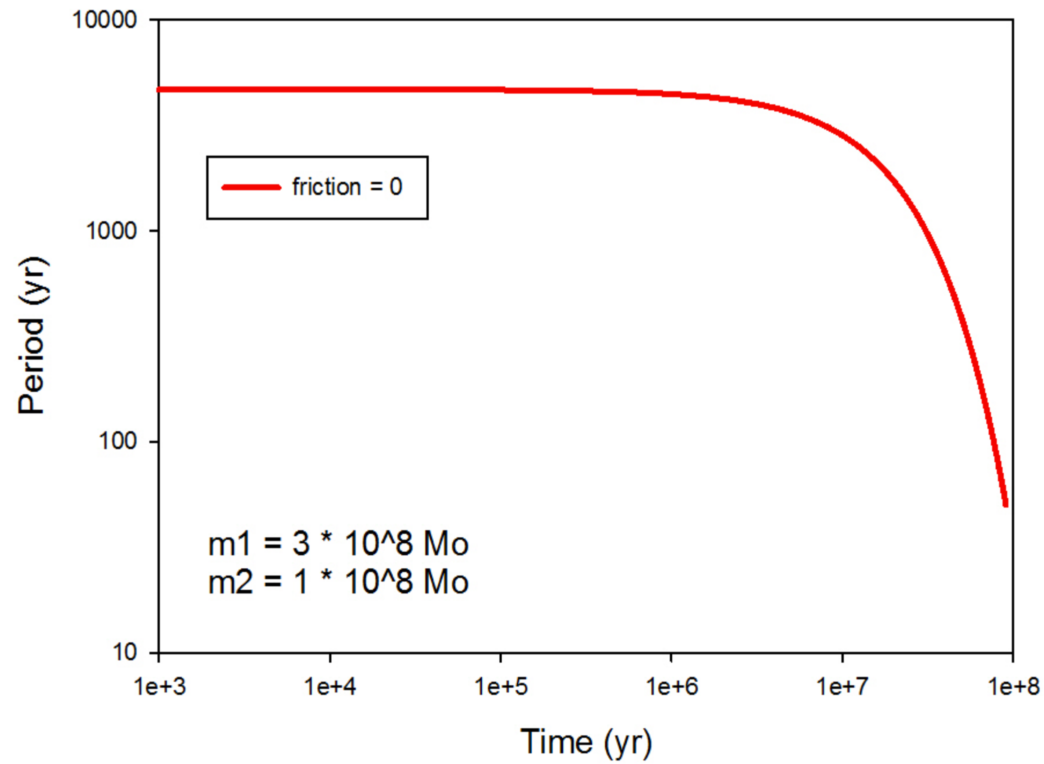
- assuming an isotropic accretion in the orbital plane of the BBH system → we calculated the size of the BBH system and we found that it decreases.

- The perturbation of the e-p jet which is magnetically confined produces an aditional friction force.

- In a first step, we calculted the evolution of the size of the BBH system, taking into account the masses increase only.

Results





R = 1 pc

Tb = 4680 yr

T_coal_GW = 48 000 10^9 yr

after 90 10^6 yr

R = 0.065 pc

Tb = 50 yr

T_coal_GW = 0.059 10^9 yr

T_coal_GW is the time for a binary system to collapse emitting Gravitational Waves

Conclusion

During the lifetime of the radio source (< 10^8 yr)

- the size of the BBH system decreases from 1 pc to few 10^{-2} pc,
- the coalescence time of the binary system due to emission of gravitational waves decreases from 50 000 10^9 yr to few 10^{-2} 10^9 yr.

- One can expect to have one collapse every few years,
- the collapse will be observable by low frequency gravitational wave detectors ,
- with a sensitivity of the order of 10^{-20}, these collapse will be observable regardless of their distance.

References : - Britzen, Roland et al. 2001, A&A, 374, 784
- Roland et al. 2015, A&A, 578, A86 and references therein

« Photo » of a BBH system by Bertha Sese